Space Weather Technical Forecast

Issued on Friday, 24 March 2023 at 13:40 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Further Minor/Moderate Geomagnetic Storms expected with a chance of Moderate storms on Days 1-2 (24-25 Mar). Daily Slight Chance of R1/R2 Radio Blackouts.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low over the past 24 hours with occasional C-Class flares. There are currently 5 numbered and three unnumbered regions on the visible disc. AR3259 in the southwest quadrant generated the largest flare of the period, a C1.7 at 24/0607 UTC. AR3256 in the southeast quadrant remains the largest and most complex region on the disc, however, a small delta spot in its trailing group has recently faded. One unnumbered Csi/Beta region in the northeast quadrant has recently been reclassified as a separate sunspot to AR3260, with small trailing spots recently proliferated. Otherwise, the remaining regions on the visible disc are mostly small, weak and magnetically stable.

No Earth directed CME's have been observed in available imagery.

Solar Wind / Geomagnetic Activity: The solar wind, as measured at L1 by DSCOVR and ACE, has largely remained at slightly elevated levels, with brief peaks to elevated levels, the highest being 513 km/s at 23/1411 UTC. Otherwise, winds have shown a gradual decline to 401 km/s at 24/0917 UTC but since 24/0922 UTC have been showing a generally upward trend and are currently around 460 km/s. This is likely to be the result of a commencing connection to an anticipated coronal hole HSS.

The solar wind density was initially above average at 24 ppcc increasing rapidly to well above average, with a peak of 63 ppcc at 23/1347 UTC. Density then dropped off sharply at 23/1407 UTC to predominantly average levels. An increase to average between 24/0225-24/0922 UTC with a peak of 35 ppcc at 24/0732 UTC. These fluctuations in density have been attributed to the arrival of CMEs, with the likely candidates released on 20 Mar.

The IMF was initially moderate, but soon increased to reach strong levels, peaking at 22 nT at 23/1418 UT, then remaining at strong levels until dropping to moderate around 24/0500 UTC. The north-south component has been predominantly negative, and mostly strongly negative from around 23/1650 UTC, with -17nT being reached at 23/1736 UTC. Since 24/0737 UTC, the north-south component has fluctuated between +6/-9nT. The phi angle was mostly positive (away from the Sun) until 24/0733 UTC, since which time it has been predominantly slightly negative (away from the Sun).

The net result of the above solar wind measures saw Geomagnetic activity increased from Active (Kp4) to predominantly G1/Minor Storm to G2/Moderate storm (Kp 5-6). G3/Strong (Kp7) storm intervals were observed in the 23/1200-1500 UTC, 23/2100-2400UTC and 24/0000-0300 UTC intervals, and a G4/Severe storm interval observed 24/0300-0600 UTC.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at Background levels.

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The high energy electron flux (greater than 2MeV) has diurnally fluctuated between Normal Background and Moderate levels, with peak flux of 116pfu at 24/0335UTC. The associated 24-hour Electron fluence remained below the Active (1e8 integrated pfu) threshold, with a steady then rapidly declining trend. At 24/0001UTC the observed fluence was 3.53e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low Solar activity is expected, with a daily slight chance of isolated M-Class flares. This risk stems from AR3256, and from the potential return of several regions onto the visible disc through the period.

Solar Wind / Geomagnetic Activity: CME arrivals during 23 and 24 Mar are the most likely cause of the current enhanced geomagnetic activity. The arrival of a CIR and from CH86/- is anticipated later Day 1. These combined effects are expected to maintain enhanced geomagnetic activity through most of the forecast period.

Initial G1-G2 Minor/Moderate geomagnetic storm conditions (Kp 5-6) are expected, these gradually declining to Active to G1/Minor storm (Kp 4-5) conditions overnight and during Day 2 (25 Mar). There is a chance of an isolated G3/Strong storm interval due to the arrival of the HSS from CH86/-. Geomagnetic activity is forecast to remain enhanced but with a gradual decline through Days 3-4 (26-27 Mar) to Quiet (Kp0-2) to Unsettled (Kp3).

Energetic Particles / Solar Radiation: High energy (greater than 10MeV) proton flux is expected to remain at Background levels, with only a Slight Chance of further enhancements should any significant flares occur.

The high energy (greater than 2 MeV) electron flux is expected to remain and Background to Moderate levels through Days 1-2 (24-25 Mar), and then gradually increase Moderate to High in response to the enhanced wind environment from CH86/-, after initially being suppressed by the enhanced geomagnetic activity. The associated 24-hour fluence is expected is also expected to rise by Day 3 (26 Mar), remaining below the Active (1e8 integrated pfu) threshold, but likely exceeding the Active threshold late on Day 4 (27 Mar).

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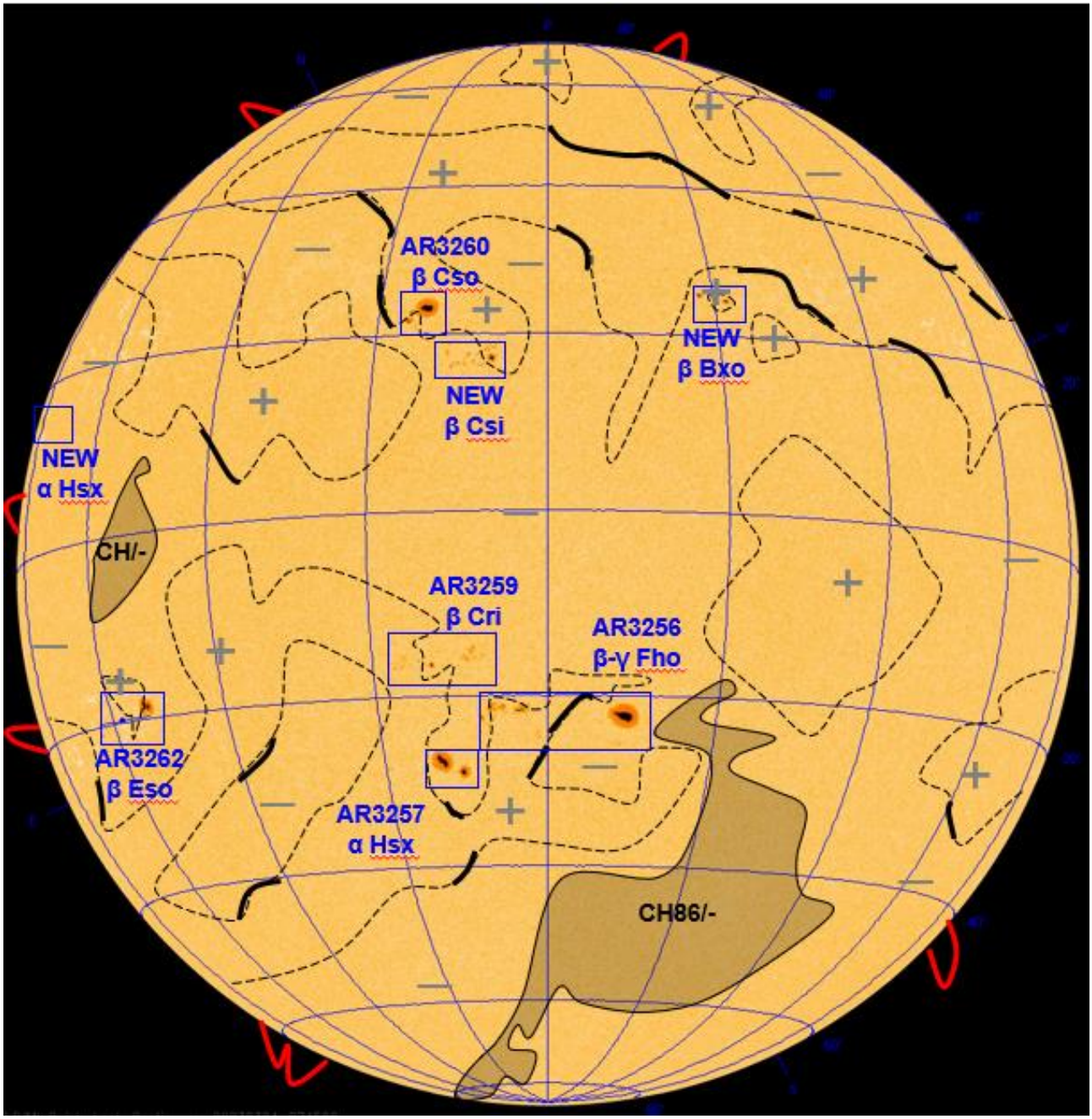
Figure 1. Solar Analysis Valid 24/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The arrival of two CMEs that left the Sun on 20 Mar and featured in the recent forecast, are the most likely cause of the enhanced geomagnetic activity that commenced on 23 Mar. The G4/Severe storm interval observed in the UTC morning of Day 1 has been attributed to the ongoing effects of those CME arrivals on 23 Mar, and an additional CME arrival.

The HSS from CH86/- is anticipated to arrive later on Day 1 (24 Mar), possibly preceded by a CIR. The Phi angle at L1 as observed by DSCOVR is currently fluctuating between weakly negative (away from the Sun) and weakly positive (towards the Sun). The Phi angle at Stereo-A became negative from approximately 23/1530 UTC, with STEREO-A approximately a day ahead of Earth, the potential arrival of a CIR and then HSS are therefore anticipated later today. The CIR may induce further

Geomagnetic storming due to possible wind speeds of 600-650 km/s within the HSS. The negative polarity of CH86 may also have a greater impact, due to the proximity to the spring equinox as per Russell-McPherron theory. Geomagnetic activity is forecast to remain enhanced whilst connection to the HSS is ongoing, with a gradual decline through Days 3-4 (26-27 Mar) to Quiet (Kp0-2) to Unsettled (Kp3).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	100	70	40	10
Strong	G3	Yes	30	25	5	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

No further CMEs are expected during the forecast period.

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Figure 2: Solar wind parameters for past 24 hours observed at L1 by DSCOVR and ACE

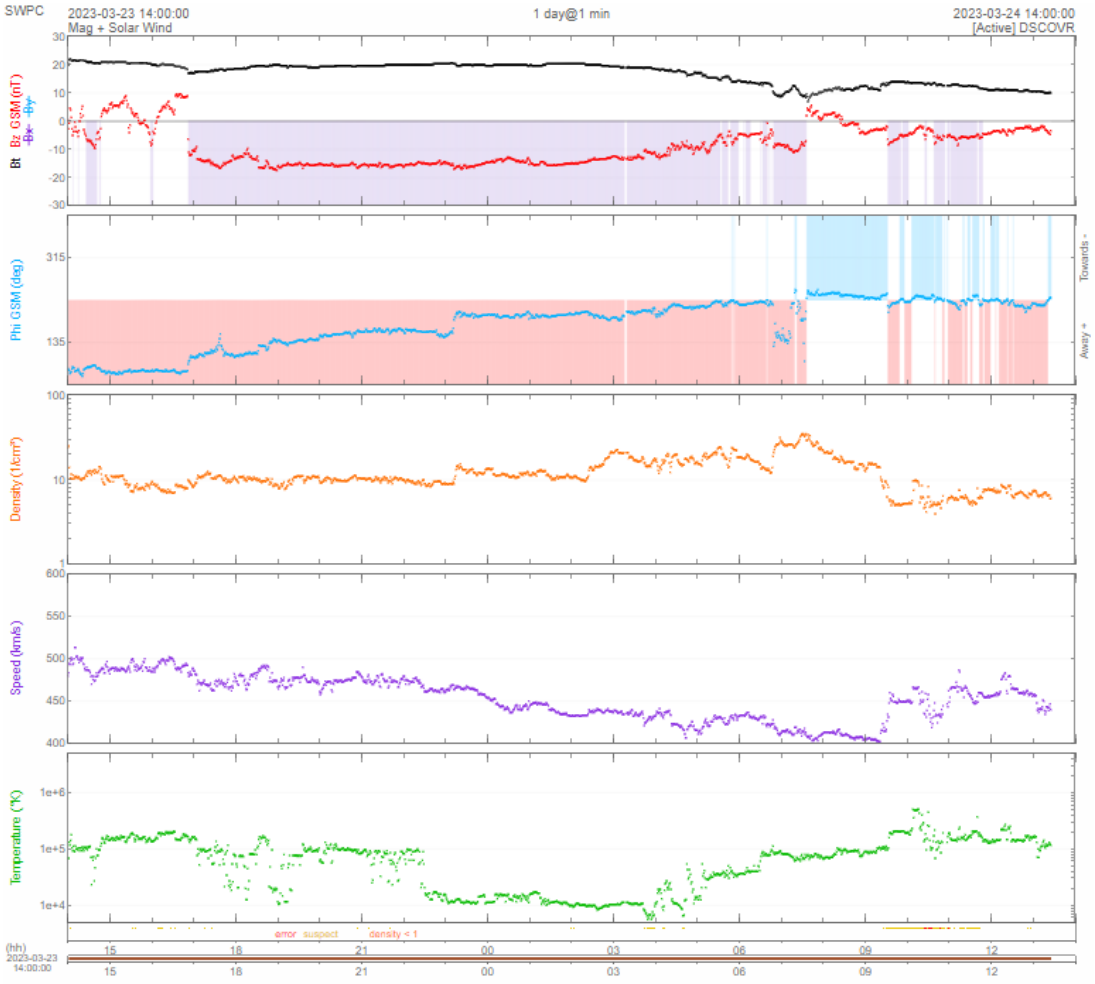
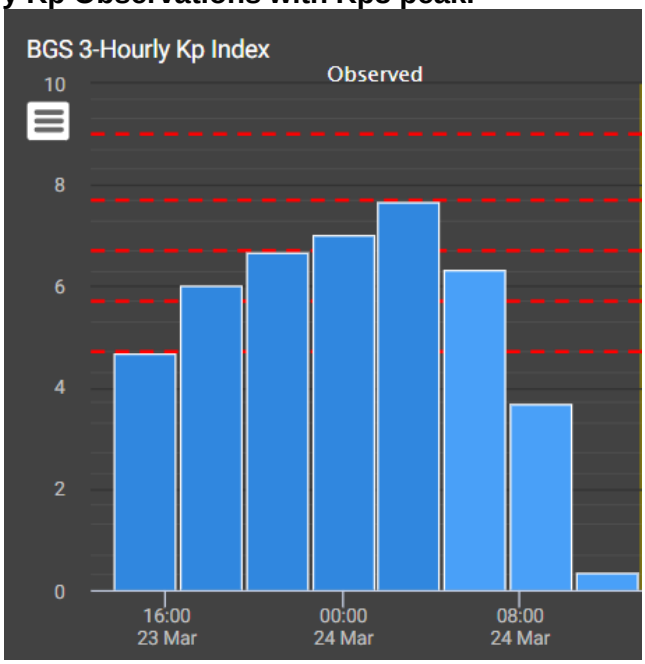


Figure 3: BGS 3-Hourly Kp Observations with Kp8 peak.



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Radio Blackouts - X-Ray Flares:
Solar activity is most likely to be Low through this period, but with a daily Slight Chance of Moderate activity. This is a result of a number of regions including AR3256, which are expected to become geoeffective through the period.

There are currently 5 numbered and three unnumbered regions on the visible disc. AR3256 in the southwest quadrant remains the largest and most complex region on the disc. One unnumbered Csi/Beta region in the northeast quadrant was recently reclassified as a separate sunspot to AR3260, with small trailing spots recently proliferated. Otherwise, the remaining regions on the visible disc are mostly small, weak and magnetically stable.

The Carrington locations for up to three returning groups lie near the eastern solar horizon, and so the risk of significant flares may increase later in the period if and when they rotate onto the visible disc.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	10	10	10	10
Very Active	R3 to R5 X Class	No	1	1	1	1

Figure 4: X-Ray Trace observed by GOES-16 and GOES-18

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Solar Radiation Storms - (High Energy Protons):
High energy proton flux (greater than 10MeV), as observed by GOES16 is currently at Background levels.

Overall little change is expected through the forecast period, although there remains a Slight Chance of future enhancements from one of the larger filaments should they erupt in addition to any active regions which may potentially rotate onto the visible disc.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):
The high energy (greater than 2 MeV) electron flux is expected to remain at Background to Moderate levels through Days 1-2 (24-25 Mar) due to suppression by current geomagnetic activity. As these effects wane, flux is then likely to increase in response to the enhanced wind environment associated with the HSS from CH86/-, diurnal variations between Moderate and High are likely through Days 3-4 (26-27 Mar). The associated 24-hour fluence is also expected to rise by Day 3 (26 Mar), to remain close to but below the Active (1e8 integrated pfu) threshold. Likely exceeding the Active threshold late on Day 4.

MOSWOC REFM is considered to be offering reasonable guidance, in keeping the fluence below the Active threshold through Days 1-3.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	10	20	30	50
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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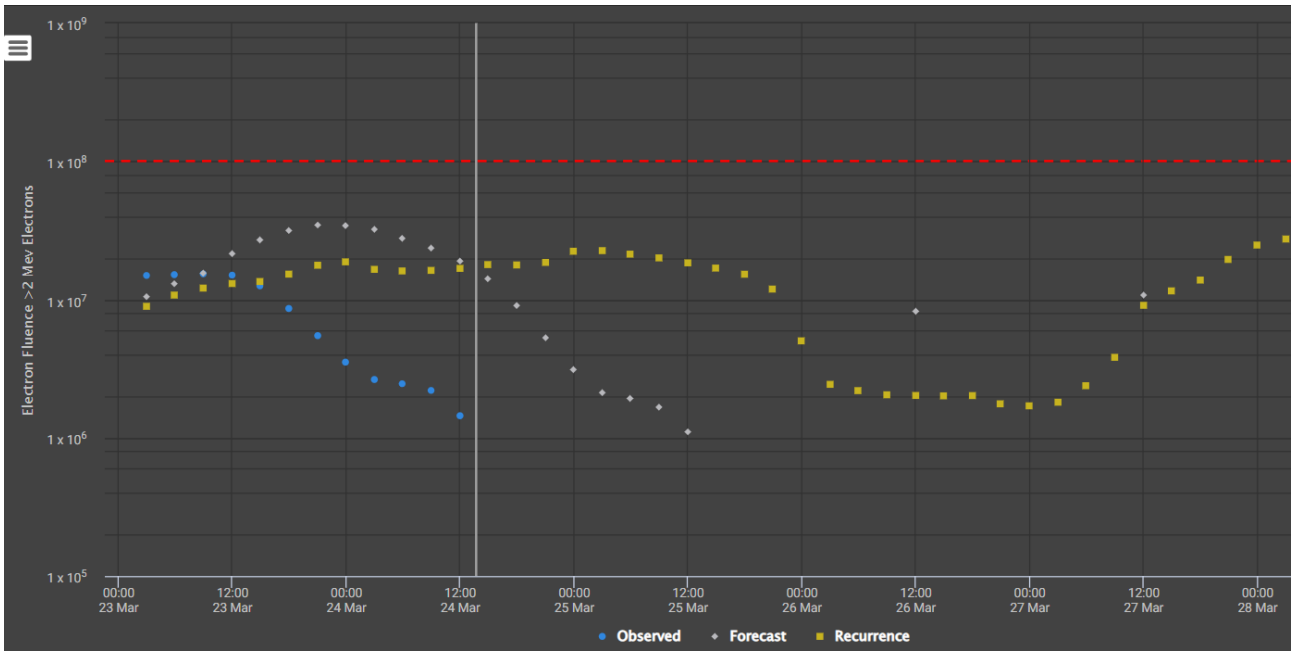
Figure 5: MOSWOC REFM



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